Water column biogeochemistry of a pristine and a human-impacted Tanzanian mangrove system

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Introduction

►The work presented here is part of the EC-funded project "PUMPSEA" (Peri-urban mangrove forests as filters and potential phytoremediators of domestic sewage in East Africa". PUMPSEA aims at providing the necessary scientific background to demonstrate the ecological and economic service which peri-urban mangroves provide by mitigating coastal pollution through sewage filtration, and to offer innovative solutions for the exploitation and management of this quality.

►We compared the water column characteristics (in terms of physico-chemical parameters, nutrient levels, organic and inorganic carbon pools and their stable isotope composition) in two contrasting mangrove ecosystems in the vicinity of Dar es Salaam, Tanzania.

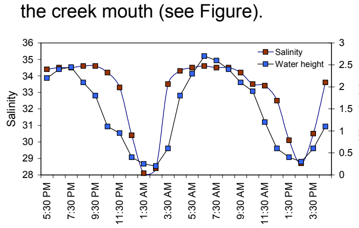
Study areas

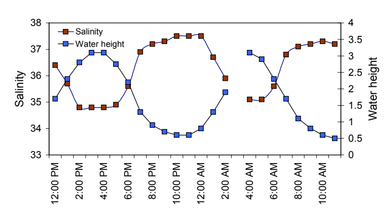
Mtoni (impacted)

Ras Dege (pristine)

►The Mtoni mangrove site is located within Dar es Salaam, and opens into the channel that passes the city's harbour. Samples were taken along the salinity gradient of the creek, and a 24-h cycle was carried out at a station not far from the creek mouth (see Figure).

►Ras Dege is located approximately 25 km. south of Dar es Salaam and has no major towns or villages in its vicinity. Samples were taken at several stations in the different creeks, and a 24-h cycle was carried out at an upstream station in the most eastern creek (see Figure).





►Due to the absence of freshwater inputs at Ras Dege (except for surface runoff during the wet season), the inner parts of the creeks experience a higher salinity than near the connection to the Indian Ocean, due to evaporation effects and porewater influence. This contrast is reflected in the diurnal salinity variations at both sites (see Figures): whereas Mtoni shows 'typical' salinity variations, the creek waters of Ras Dege is highly saline at low tide (up to 38 during the sampling period) but salinity decreases as the oceanic water mixes in at high tide. Such inherent differences will of course need to be taken into account when interpreting differences in biogeochemical signatures or processes.

Acknowledgements

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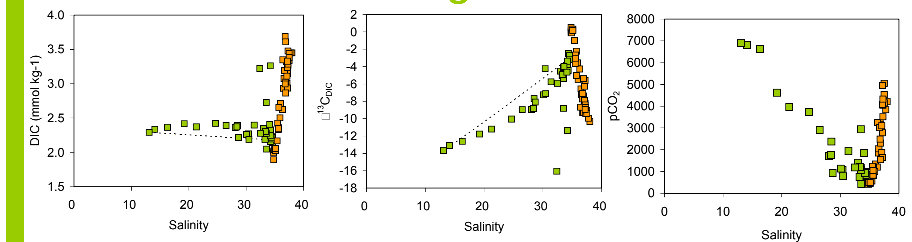
http://www.vub.ac.be/mangrove

Pumpsea

Peri-urban mangrove forests as filters and potencial phytoremediators of domestic sewage in East Africa

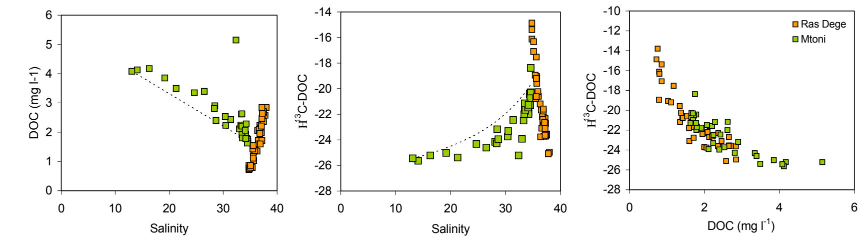
http://www.pumpsea.icat.fc.ul.pt/main.php

Dissolved inorganic carbon



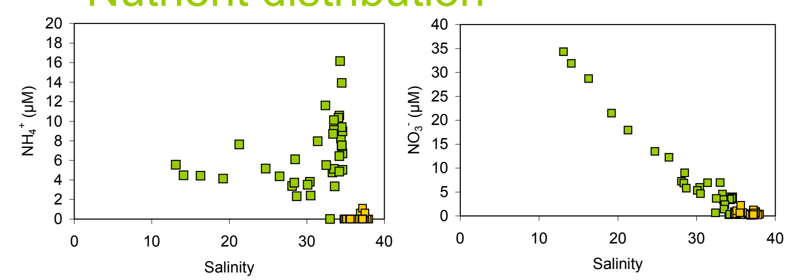
For the total DIC pool, clear internal production could be observed along the Mtoni profile, and the negative excursion of $\delta^{13}C_{DIC}$ from the theoretical conservative mixing scenario indicates that these inputs are due mineralization. Such a pattern has been observed in a number of other mangrove creeks/estuaries (e.g. Gazi Bay, Kenya; Tana delta; Kenya) and illustrates the importance of organic matter decomposition. In Ras Dege, total DIC levels were on average markedly higher than in Mtoni, which is likely to be related to the longer residence time in this system, and the subsequent build-up of a large DIC pool. pCO_2 values varied widely, but showed a strong oversaturation in both systems.

Dissolved organic carbon



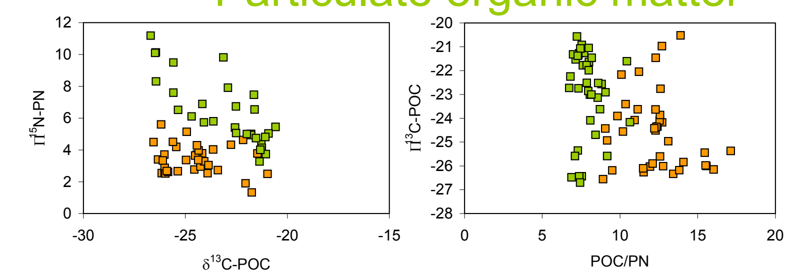
The Mtoni DOC profile shows a clear non-conservative pattern, and $\delta^{13}C_{DOC}$ data indicate that these DOC inputs have a $\delta^{13}C$-signature (~-26 to -28 ‰) in line with what is expected for mangrove/terrestrial C3 inputs. Ras Dege shows a much lower the range of DOC, and oceanic inputs at this site have a much lower DOC content than at Mtoni. The DOC-$\delta^{13}C_{DOC}$ plots of both sites are consistent with mixing of two distinct sources: (i) a low DOC, ^{13}C-enriched (marine) end-member, and (ii) a high DOC, low $\delta^{13}C_{DOC}$ end-member. For Mtoni, the marine $\delta^{13}C_{DOC}$ (~-20 ‰) are consistent with a phytoplankton-based source, whereas at Ras Dege values are much more enriched and point towards a contribution by seagrass-derived carbon.

Nutrient distribution



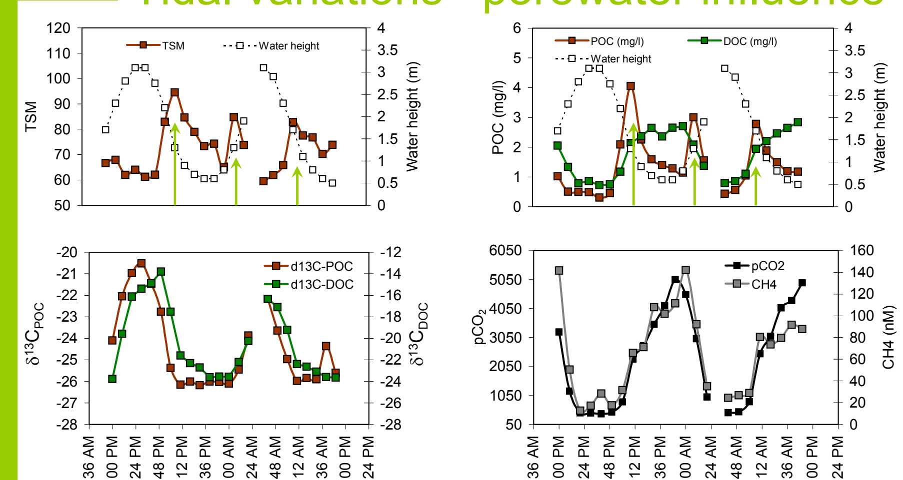
Profiles of dissolved inorganic N species (NH_4^+ and NO_3^-) show very distinct nutrient levels in both sites, being significantly higher in Mtoni than in Ras Dege. For NH_4^+, the Mtoni profile shows clear non-conservative behaviour, with distinct removal of NH_4^+ inputs (originating fom the marine end of the creek). For NO_3^- in contrast, highest inputs originate from the freshwater part of the creek (up to ~35 µM at the lowest salinity sampled), but the NO_3^- distribution is otherwise conservative. For PO_4^-, no marked differences between both sites were found, with concentrations generally in the range of 0.1 to 0.4 µM (data not shown).

Particulate organic matter



The suspended matter pool at both sites showed clear differences in their biogeochemical characteristics, and when considering multiple characteristics (e.g. POC/PN, $\delta^{13}C$, or $\delta^{13}C$ and $\delta^{15}N$), the data from both sites cluster out with little overlap: although the range of $\delta^{13}C_{POC}$ at both sites is similar, suspended matter is clearly differentiated on the basis of its higher $\delta^{15}N$ at Mtoni and distinctly higher POC/PN in Ras Dege. These higher $\delta^{15}N$ signatures are also observed in other biological compartments (sediment, flora, fauna) and could offer a powerful integrated measure of anthropogenic N inputs into these ecosystems.²

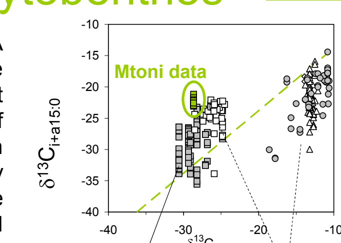
Tidal variations –porewater influence

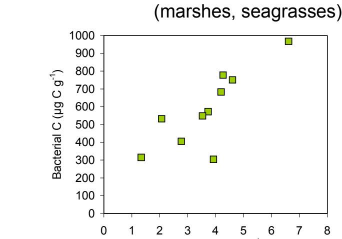


Diurnal variations of suspended matter at Ras Dege (TSM, POC) showed distinct maxima (arrow on upper 2 panels) during periods of high flow, indicating scorging or resuspension effects. Variations in DOC, in contrast, appeared to be only related to the water level fluctuations, and were highest at low tide, when inputs from porewaters were high as indicated by the high salinity levels. The origin of POC and DOC ($\delta^{13}C$) both varied with the tide, but variations in $\delta^{13}C_{DOC}$ had a larger amplitude and showed a time lag with respect to $\delta^{13}C_{POC}$, resulting in large differences in their origin during high tide periods (up to 8 ‰). Variations of pCO_2 and CH_4 coindided strongly and followed the water level closely, indicating a strong porewater signal and a limited biological influence in the creek water itself.

Importance of microphytobenthos

When comparing $\delta^{13}C$ data of i+a15:0 PLFA (bacterial fatty acid markers) with those of the dominant vegetation (mangroves), we find that in comparison to literature data from a variety of other mangrove systems (the figure shown includes data from different but all relatively pristine sites in Kenya, India, and Sri Lanka), the Mtoni $\delta^{13}C_{PLFA}$ data are the most ^{13}C-enriched found so far, pointing towards a strong contribution by (^{13}C-enriched) benthic microalgae in sustaining mineralization. A second line of evidence for such a strong link is the positive correlation found between the abundance of 20:5ω3 (a diatom marker) and the estimated bacterial C stock in the sediments (based on the abundance of certain fatty acid markers).





We can hypothesize that the anthropogenic nutrient inputs in Mtoni support a high benthic production (as can be seen visually in the Mtoni creek sediments by abundant diatom mats, see photo), which in turn provide a significant and labile C input for sediment bacteria.

The effect of (benthic) primary production by microalgal mats and/or *Ulva* sp. can also be traced in the surface water $\%O_2$ levels, which in some cases reached > 140 % at Mtoni.

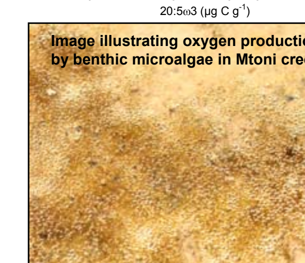


Image illustrating oxygen production by benthic microalgae in Mtoni creek